The Battle for Creativity: Frontiers in Science and Science Education

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Introduction

The importance of sociocultural influences in contextualising and contemporising teaching and learning is a recurrent theme in science education and many countries are currently implementing new pedagogical paradigms aimed at reversing a persistent trend of declining enrolments in science subjects.

Rhetoric surrounding the best and most effective methods for reframing public perception and enhancing student engagement tends to focus on the need to generate a technologically competent workforce and the economic, environmental and social benefits associated with initiation and development of novel technologies and industries \(^1\text{-}^3\). Although it is implied that the goal of reform is to assure sustained quality and originality of intellectual output, there is little to no acknowledgement, or analysis, of embedded sociocultural practices that oppose and suppress creativity.

What is Science?

Any given domain of scientific practice occupies a nexus between sub-fields and the current pace of scientific and technological progress means that new disciplines are continually emerging \(^1\text{-}^3,^4\). Despite projected increases in employment opportunities within science and technology sectors \(^3,^5\) however, enrolments in science subjects are in decline \(^5,^6\).

Surveys of student and community attitudes identify rote learning and rigid, dogmatic thinking as traits seen as essential for success in science \(^6,^7\). Although many individuals recognise that science has delivered benefits in the form of medical, technological and industrial innovation \(^3,^6\text{-}^8\), they appear unable to appreciate the creativity required to extend the boundaries of scientific knowledge \(^3,^6,^7,^9\).

Individuals draw their understanding of science and scientists from a diverse array of sources; educators, peers, employers, the media, prominent journals, weblogs and popular-science books. An iconic, mimetic example is Professor Peter Medawar’s (1967) *The Art of the Soluble* and Advice to a Young Scientist (1979); which propose that the secret of success is to focus on a pseudomathematical zone of optimal difficulty (*The Medawar Zone*) because those who solve problems that are either too simple or too difficult will not be recognised and rewarded for their achievements.
Medawar’s contribution is historically and culturally significant because it reflects a culture where real currency is not quality and originality of work *per se*, but the value attributed to it by one’s peers.

The notion of knowledge as valid only when canonised through publication is enforced early in scientific education and training\textsuperscript{10,11} and the operational reality of science is therefore, one where antithetic achievements are exulted and rewarded (fiscally and socioculturally) more readily than creativity\textsuperscript{3,4,12,13}. The cultural practice of conferring disproportionate rewards on those who best appease and please their peers is however, a threat to quality science education.

At a tertiary level, the danger comes from a tendency to approach teaching positions as opportunities to avoid the perils of funding-dependent salaries, or obtain academic merit points\textsuperscript{14}. To fulfil their role as a bridge between educational and scientific practice\textsuperscript{15}, teaching positions should be occupied by those capable of effective, sustainable praxis, but current attitudes favour appointment of scientific personnel nominally reclassified as teaching staff. This reinforces exclusionary, hegemonic perceptions of science as incomprehensible and inaccessible to all but a select(ed) few of the most gifted individuals\textsuperscript{16}. The flow-on effect at secondary and primary levels is positioning of science education, and science educators, as subordinate to science and scientists.

**What is Creativity?**

Creativity is a highly contested social construct\textsuperscript{5,17,18} which occupies a unique place in the scientific arena as both a requirement for innovation and a personal characteristic that can be developed and extended through quality education\textsuperscript{7,12}. It is broadly agreed that creativity has two essential forms: a) big C creativity (BC), which describes development of transformative performances or products and; b) little C creativity (LC), which is concerned with construction of novel solutions to problems of limited relevance\textsuperscript{18}. Within this framework, LC may be considered combinatorial (establishing new connections between old ideas) or exploratory (operating within a limited domain, or limiting set of rules)\textsuperscript{17}.

Many practising scientists argue that increasing emphasis on collaborative, multidisciplinary research means the historical stereotype of the BC scientist working alone on a research project of their own devising is no longer functionally viable\textsuperscript{1}. Others contend that large scale corporatization and commercialisation of funding and facilities is the single
greatest threat to creativity and innovation\textsuperscript{12} and that enforced collaboration leads to ineffective experimentation and research\textsuperscript{13}.

Lexicographic investigations of creativity studies provide historical insights into the battle for control over perceptions of science. The word “genius” for example, originally served as collective noun relating to a communal state of transcendental insight; but has been reified as a result of processes concerned with establishing and defending a system of intellectual stratification based on quantitation of comparative ability or attainment\textsuperscript{19}. Although the reification may have been conceived and enacted with the innocuous (even noble) intention of overturning post-Darwinian reservations regarding the moral and social value(s) of science and scientists\textsuperscript{19}, it has insidious ramifications in contemporary contexts.

Adherence to an outmoded view of scientific creativity as an ephemeral, nebulous trait personified in a relatively small subset of élite individuals is dysfunctional at a societal level because there is no singularly creative archetype: Creativity correlates with a wide range of personal traits and characteristics\textsuperscript{4,17,18,20-24}; and its actualisation is the product of complex, dynamic interplay between personal and societosocial factors\textsuperscript{25}.

As long as a fundamental level of proficiency is attained, the capacity for both scientific and artistic creativity exists within all individuals\textsuperscript{26}. The crucial ingredient for realisation is not possession of innately superior neurochemical or neurobiological structures or schemata, but access to opportunities to refine and improve speed and processing capacity\textsuperscript{26}. Positioning and practice of science as distinct from other areas of liberal intellectualism is problematic because it means that very few individuals are granted full and equal access to those opportunities\textsuperscript{26}.

**Teaching for Creativity**

Interest in creativity as a core goal of education programmes is presented as a progressive, inclusive ideologue, but those familiar with mechanisms and processes of education reform recognise the new rhetoric as a reactionary discourse, motivated by perceived mismatches between educational practice and workforce requirements\textsuperscript{27}. Criticisms of this nature are often dismissed as misguided political correctness or resistance to change, but this is an ill-informed view that fails to acknowledge the transformative power of quality education.

Regardless of the field of endeavour, the pace of social and technological change means what is taught or learned in education and training will be irrelevant to workplace
practice within five years \(^{28}\). Any reform of educational policy and practice will therefore be ineffective unless it acknowledges that prescriptive approaches only ever meet the needs of a relatively small number of individuals, for a limited period of time \(^{29}\).

There is no doubt that traditional models of teaching and learning have cultivated perceptions of science as a non-creative endeavour and overt emphasis on dogmatic adherence to rules of the discipline is not only a deterrent for students \(^{6,7}\), it is incompatible with the true nature of science \(^{30}\).

Success in science does depend on acquisition of subject-specific knowledge \(^{31}\), but expertise and proficiency develop via processes that are paralleled across all domains of human activity, as individuals navigate through a dynamic landscape of physiocognitive, psychological and sociocultural challenges \(^{32}\). Distinction between non-creative and creative individuals is meaningless because domain knowledge and higher-order procedural/strategic knowledge develop in tandem \(^{31,33}\), as individuals develop personalised awareness of the recursive, evolving status of all knowledge \(^{34-36}\).

Surveys of science educators reveal a deep conviction that creativity should be a central focus of education programs \(^{8,37-39}\). In practice however, many feel constrained by pragmatic issues \(^{8,13,40}\), which make it relatively easy to implement normalised, accepted teaching and learning practices, but difficult to effect genuine innovation.

**Frameworks for Quality Education**

Decades of research have demonstrated that quality education requires: a) unambiguous articulation of goals and requirements; b) acknowledgment that there may be more than one way to achieve desired outcome/s; c) activation of intrinsic motivation and; d) learning and assessment tasks that support acquisition and development of deeper understanding, as well as obvious skills and abilities \(^{27,41,42}\). The process of designing and implementing learning programs in accordance with these principles is however, hampered by successive waves of reform that oscillate between excessive and insufficient emphasis on fundamental skills.

Knowledge and conceptual understanding are prerequisites for success in any field, but the value attributed to any specific skill or knowledge also depends on the sociocultural environment \(^{27}\). Assertions that the skills and abilities essential for success are possessed by an élite subset of the population leave many students convinced that they possess no natural
aptitude or ability\textsuperscript{43}, but scientific knowledge is not an innate, bivariate (present or not) trait expressed in a single (validated/canonised) dialect.

The likelihood of any given individual generating creative output cannot be predicted or controlled in any precise sense. There is no direct relationship between IQ and giftedness and likelihood of creative output depends on a complex combination of social, psychological and intellectual traits and events\textsuperscript{44}. This means that, regardless of their status as gifted or non-gifted in childhood, all individuals are capable of reaching at least an LC stage of development.

Transition from LC to BC can be facilitated through contextualised, problem-solving approaches\textsuperscript{5} and these have a long history in science education\textsuperscript{9}. Presentation of complex tasks based on real-world questions or problems clearly develops higher-order cognitive skills through provision of opportunities to gain experience in design, problem-solving and decision making\textsuperscript{8,9,39}; but implementation in a manner that is incompatible with the prior knowledge and experience of the student population may also lead to disengagement and confusion\textsuperscript{8,31,40}.

Ultimately, the success of inquiry-based programmes relies on both pedagogical and content knowledge, because good teaching demands a dynamic, flexible approach that can be adapted to meet the unique and situated needs of an ever-changing array of students and settings\textsuperscript{13}. This is the foundation of the developmental/constructivist notion of the \textit{zone of proximal development}; which requires learning environments structured to provide all students (regardless of current ability) with opportunities to extend their knowledge and conceptual understanding\textsuperscript{10,45}.

To avoid perpetuation of a validation-by-consensus culture\textsuperscript{10,40}, science education must not be confined to prescriptive delivery of mandated content. Removing an education professional’s capacity to respond to temporal and individual variation in student interests and inclinations is ideologically offensive; in the same sense that attempts to quantify the creative output of different races are offensive because they arbitrarily elevate a single way-of-being above others.

\textbf{Identifying and Colonising Loci of Sustainable Praxis}

Within the current operational reality, Popper’s postulate that scientific progress occurs through systematic identification, and incremental extension, of the limits of existing
theory has been decoupled from Kuhn’s concept of anomalies and contradictions as indications that existing schemata require reconfiguration, or abandonment. The resultant inability, or unwillingness, to acknowledge that transformative advances almost invariably come from individuals that operate (at least initially or temporarily) on the periphery has a direct effect on the quality of science and science education.

The necessity of ruptures with prevailing theory and practice has been demonstrated in the context of transformative advances in geographical science. Deployment of Foucault’s idea of heterotopian loci (initially independent intellectual positions beyond the realm of accepted practice which are colonised by an increasing number of individuals as the meme takes hold) indicates that advances in technology have the potential to accelerate either assimilation of heterotopian perspectives, or reinforcement of the self-authenticating status quo. A tendency, in science, for ostracism of those who extend their domain of practice beyond accepted boundaries to be justified by contention that skepticism is essential to good practice therefore means that any individual(s) who articulates or occupies a locus (loci) of creative praxis is vulnerable.

This is problematic because it exacerbates tensions between philosophies and practices in science and science education. Education experts generally agree that collaboration with scientists is beneficial in development of learning programmes, but subjugation of education and educators is incompatible with developing and maintaining a capacity for creativity because this requires individuals at all levels of education and practice to be granted full and equal access to opportunities that will allow them to:

a) acquire a high level of domain-specific knowledge;

b) practise application of that knowledge in a range of situations and;

c) be challenged to link domain-specific knowledge to other fields by solving problems with personal relevance.

Conclusion

Surveys of student and public perception consistently indicate a lack of appreciation of science as a creative endeavour. This is a significant deterrent to students and is inconsistent with the nature of science as a dynamic, multidisciplinary undertaking where ideas and concepts are non-static entities that can, and should, change when contradicted by experimental evidence. Inquiry-based approaches to science education have tremendous pedagogical potential, but effective implementation requires commitment to establishment
and maintenance of operational realities that allow scientists and science educators to identify and colonise loci of sustained creative praxis.

References
